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Diel activity patterns of fishes of special interest in the Sacramento-San Joaquin River Delta

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Introduction

The Delta Juvenile Fish Monitoring Program (DJFMP) has monitored populations of juvenile fish species throughout the Sacramento-San Joaquin River Delta waterways since the 1970's to provide managers of Delta water operations with information on patterns in distribution and abundance of juvenile fish found throughout Delta waterways. Previous sampling by the DJFMP has been conducted primarily during morning and mid-day hours. As a result, little is known about the diel patterns in abundance of juvenile fish. Knowledge of diel activity patterns of species of special interest could assist water operations facilities in making informed decisions regarding pumping schedules to minimize impacts on these species. Although information on nocturnal and crepuscular habits of fish is limited, recent evidence suggests that various fish in the Sacramento-San Joaquin River Delta exhibit distinct diel patterns in activity levels (Harvey et al. 1999, Bennett et al. 2002, Wilder & Ingram *in press*, L. Grimaldo *pers. comm.*).

The purpose of this study was to examine diel patterns in catch per unit effort (CPUE), a proxy for activity level, of fish species of management and/or recreational interest during three specific occasions when the DJFMP sampled over a continuous 24-hour period. Although we wanted to include all "Pelagic Organism Decline" (POD) and recreationally fished species, we report only on species for which we had sufficient catches – delta smelt, longfin smelt, Sacramento splittail, striped bass, and American shad.

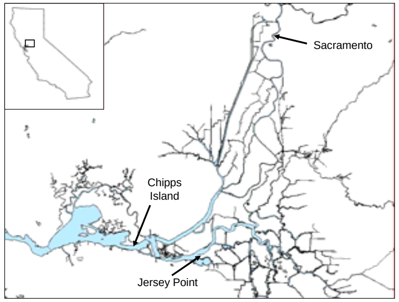


Figure 1. Map of sites in the Sacramento-San Joaquin River Delta.

Methods

We conducted either Kodiak or midwater trawls at Chipps Island, Jersey Point, and Sacramento during three separate sampling periods (Table 1, Figures 1, 2A-B). During each sample period, 10-20 minute trawls were conducted for >24 h on a near continuous basis. For each trawl, we also measured water temperature and water clarity using a Secchi disk (during daytime trawls only). All trawls were categorized as occurring in one of three times of day: (1) diurnal, (2) nocturnal, or (3) crepuscular, which we define as the periods either between first daylight and sunrise or between sunset and last daylight.

Individual fish were identified to species level and counted after each trawl (Figure 2C), and their CPUE (in fish/m³) was calculated as:

$$CPUE = \frac{catch\ \ per\ \ tow}{net\ \ mouth\ \ area\ \ x\ distance\ \ sampled}$$

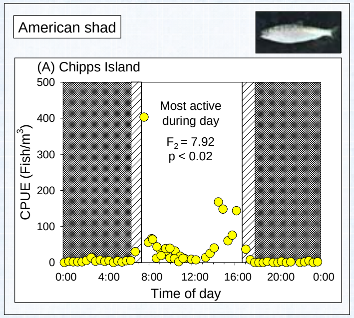
To test for differences in CPUE of each species among times of day in each sampling period, we employed nonparametric ANOVAs. If significant differences among times of day in mean CPUE were found, we used a Tukey-type non-parametric multiple comparisons test to determine which means were different.

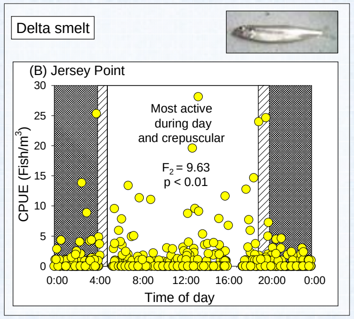
Table 1. Summary table for sampling periods in the study. Mean values (±1 SE) for water temperature, daylight hours, and water clarity were calculated across an entire sample period.

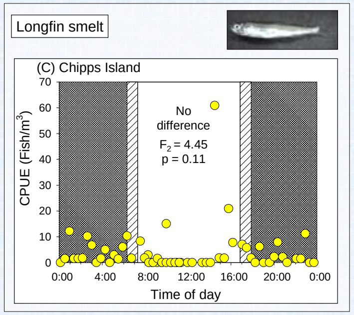
Study site	Sample period	Trawl type	Mean water temperature (°C)	Mean daylight hours (h)	Mean water clarity (m)
Jersey Point*	4/29/97-5/15/97	Kodiak	18.0 (0.1)	13:58 (0:02)	0.58 (0.01)
Chipps Island	12/11/03-12/12/03	Midwater	11.5 (0.1)	09:34 (0:01)	0.66 (0.01)
Sacramento	5/17/06-5/18/06	Midwater	16.9 (0.1)	14:19 (0:01)	0.62 (0.00)

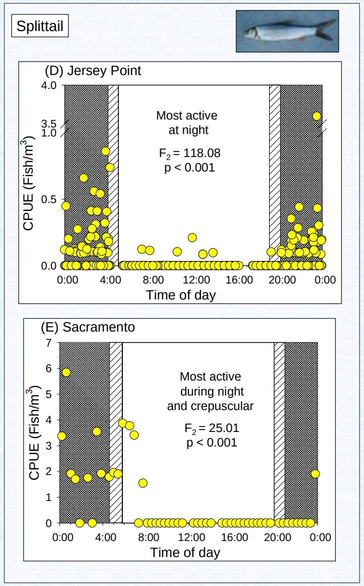
*Data collected by Hanson Environmental

Figure 2. (A) Kodiak trawl, (B) midwater trawl, and (C) field technician counting and measuring fish.









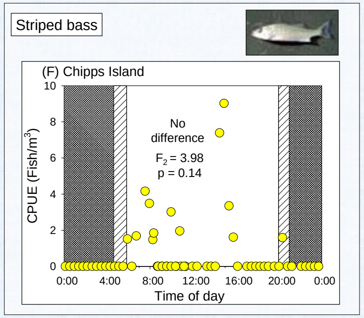


Figure 3. Diel patterns in CPUE of (A) American shad, (B) delta smelt, (C) longfin smelt, (D-E) splittail and (F) striped bass. Shaded regions indicate night, hatched regions indicate crepuscular hours, and white regions indicate daytime. All values were multiplied by 10,000 for ease of viewing. Note change in scale among patterns.

Results

- American shad were primarily diurnal;
- Delta smelt were active primarily during the daytime and crepuscular periods;
- Longfin smelt and striped bass activity followed no discernable pattern;
- Splittail were most active during nocturnal and crepuscular times of day (Figure 3, Table 2).

Table 2. Results table of fish species sampled in the study. Mean values (± 1 SE) for fork length size were calculated across an entire sample period.

Species	Location	Sample dates	Trawl type	Trophic level	Active period(s)	Mean fork length in mm (SE)
American shad	Chipps Island	12/11/03-12/12/03	Midwater	Zooplanktivore	Diurnal	83.6 (0.4)
Striped bass	Chipps Island	12/11/03-12/12/03	Midwater	Piscivore	All equal	113.0 (5.5)
Delta smelt	Jersey Point	4/29/97-5/15/97	Kodiak	Zooplanktivore	Diurnal/ crepuscular	52.6 (1.1)
Longfin smelt	Chipps Island	12/11/03-12/12/03	Midwater	Zooplanktivore	All equal	106.2 (1.4)
Sacramento splittail	Jersey Point	4/29/97-5/15/97	Kodiak	Juv: Zooplanktivore; Adult: Benthic Invertivore	Nocturnal	46.8 (3.8)
	Sacramento	5/17/06-5/18/06	Midwater	Juv: Zooplanktivore; Adult: Benthic Invertivore	Nocturnal/ crepuscular	29.4 (1.3)

Discussion

Differences in diel activity patterns among species in this study (Figure 3) are likely due to a combination of these and other factors:

Foraging Efficiency: Visual predators tend to be active during daytime or crepuscular periods to maximize their foraging efficiency. However, because all fish in this study are visual predators, this factor alone is not sufficient to explain the patterns observed among species (Table 2).

Predation Risk: Predation risk varies among times of day for species with visual predators. However, because all fish in this study have visual predators (e.g., birds, mammals, and piscivorous fish), this factor alone is not sufficient to explain the patterns observed among species.

Size: There is evidence that larger fish tend to be more nocturnal than smaller fish, possibly because digestive rates are lower in these fish and they do not need to forage during the day when foraging efficiency is greatest (Hiscock et al. 2002). Our findings are not consistent with this mechanism, although there does appear to be a size-related pattern in activity level. Splittail, the smallest fish in this study, was nocturnal; American shad and delta smelt, mid-sized fish, were diurnal; and activity levels of striped bass and longfin smelt, the largest species, did not vary among times of day (Table 2). These patterns, however, do not account for variation among species in size at a given life stage.

Time of Year: Differences in temperature, water clarity, and day length between spring and winter sampling periods may influence fish metabolism, net avoidance, and amount of time being active, respectively, all of which can influence temporal patterns in CPUE (Table 1, Wilder & Ingram *in press*). Striped bass and longfin smelt, which were present only during winter sampling, were the only species that did not show patterns in diel activity levels. Splittail, which was abundant only in spring sampling, was the only fish to exhibit strong nocturnal activity levels.

Location: Differences in temperature and water clarity among locations within the Delta, albeit small, may influence fish metabolism and net avoidance, which can influence temporal patterns in CPUE (Table 1, Figure 1). However, splittail were nocturnal at both upstream (Sacramento) and downstream (Jersey Point) sites. Also, multiple patterns in diel activity were observed in fish at downstream locations.

Knowledge of diel activity patterns of species of special interest and mechanisms responsible for these patterns should be of paramount interest to water operations in the Delta. Such knowledge could allow water operators to minimize impacts on these species by timing water operations during the inactive periods of these species.

References

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